Time-Domain Measurements of Broadband Antennas

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Abstract

One of the tasks of the European Antenna Centre of Excellence (ACE) is to investigate the time domain systems for antenna measurements, especially for ultra-wide band (UWB) antennas. In this paper, different time-domain measurement systems from three different organisations within the ACE are described and discussed along with some measured results. Some discrepancies and problems are identified. These systems will be used to measure a number of different antennas from the participating organisations - it is aimed to produce a good practice guide for people to conduct broadband antenna measurements using a time-domain system (either network analyser based or pulse generator based). Measured results will be collected and compared and the final outcome will be reported at the European Conference on Antennas and Propagation (EuCAP) 2007.

1 Introduction

Ultra-wideband (UWB) antennas have recently attracted a lot of attention, which has resulted from a number of reasons such as the potential for increased communication data rate and the increased number of services [1]. Unlike the conventional UWB antennas (which are mostly large directional antennas, such as the double rigid horn and TEM horn antennas), the new UWB antennas for 3.1 to 10.6 GHz are small and omni-directional. This has raised the question of how to conduct the antenna measurement accurately and efficiently.

The frequency domain measurement is very effective for narrowband antenna characterisation but may not be a good option for the UWB antenna measurements if the measurement is to be conducted over the whole frequency band. At the moment, the common view is that the time-domain technique should be a good option for such a broadband measurement. This is because the time-domain method has a number of unique advantages, such as

- Removal/reduction of reflection: the reflection caused by mismatch and unwanted reflections in the antenna range can be removed by using time gating techniques.
- Simple measurement system set-up: the equipment is less complex and cheaper than the comparable frequency-domain equipment.
- Efficient in broadband measurement: just one complete measurement provides the antenna characteristics over a wide-frequency spectrum.

The very last feature makes the time-domain measurement techniques particularly suitable for the broadband antenna measurements [2 - 4].

Generally speaking, antenna time-domain measurements have so far attracted less attention than the frequency domain measurements although quite a lot of work has already been done. This was partially due to the fact that there had not been much demand for such a service.

For antenna pattern measurements in the time domain, it takes longer than the frequency-domain measurement for a rotation of 360 degrees. But once the measured results are transferred to the frequency domain via the FFT, radiation patterns over a wide frequency band can be obtained. Thus this method is good for broadband measurements but less attractive for narrowband measurements.

This paper is aimed at reporting the recent activities of the ACE (which is funded by the EC FP6) in this area. A number of organisations (Liverpool, Warsaw and Delft) are involved in this work package. It was agreed that a number of selected broadband antennas will be measured at these participating organisations in the time and frequency domains. These selected antennas will cover both the directional and omni-directional antennas for the frequency band from 3 to 11 GHz. The detailed collaboration work of each party is yet to be completed which is scheduled to complete by the end of September 2007. Results will be collected and compared; the final outcome will be reported at the EuCAP in Nov. 2007. Through this measurement campaign, it is aimed to produce a good practice guide for people to conduct broadband antenna time-domain measurements.

In this paper some system set-ups and initial results are presented. Comparison of some patterns obtained by frequency domain measurement for antennas will also be reported in this paper. Challenging issues such as how to obtain the 3D radiation pattern via the time domain technique, will be addressed in our study.

2 Measurement Systems and Results

There are basically two types of time-domain systems. One is pulse generator based system which typically consists of a pulse generator and receiver/oscilloscope. Another one is a network analyser based system which should have the time-domain option for this application. Both systems are covered by this partnership.

2.1 Liverpool Measurement System

The measurement system at the University of Liverpool is based on a vector network analyser with the time-domain option (Anritsu 37369A). The frequency range is from 40 MHz to 40 GHz. A commercial double rigid horn antenna (HF906) is employed as the transmitting antenna to cover the frequency range of 1 to 18 GHz with a return loss more than 10 dB. The antenna positioning and data acquisition system is DAMs6000 Antenna Measurement System which is suitable for frequencies up to 18 GHz with Azimuth Axis continuous 360° rotation and 1/4° increments, Elevation± 45° and 1° increments. The complete system setup is shown in Fig. 1. It is placed inside an anechoic chamber of dimensions 6m x 3.5m x 3m, as shown in Fig. 2, which performs well above 800 MHz.

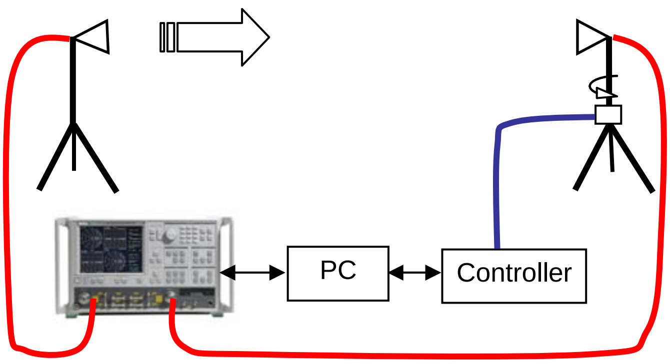

Figure 1 Measured system setup at Liverpool

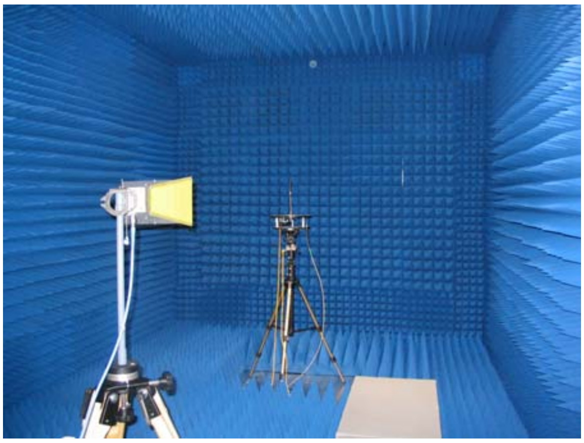

Figure 2 Measurement positioner and chamber

For the UWB measurements (3 to 11 GHz), the transmitting and receiving antennas are normally separated by about 2.5m. The maximum output power from the network analyser is 0dB, using Friis transmission formula and taking the cable loss into account we can figure out the measurement dynamic range. It has been noticed that power transmitted from a network analyser sometimes is too small to cover the dynamic range required for certain antennas, thus the operational distance has to be reduced, otherwise the low level signals are mixed with noise and the results are therefore not reliable. The drawback is that if the separation is not enough, the far-field condition may not be met which may reduce the measurement accuracy. Thus in this case a trade-off has to be made between the plane-wave condition and large dynamic range. Alternatively a wideband power amplifier can be added to the transmitting side to boost the signal level, but this option is not cheap and we are looking into this option.

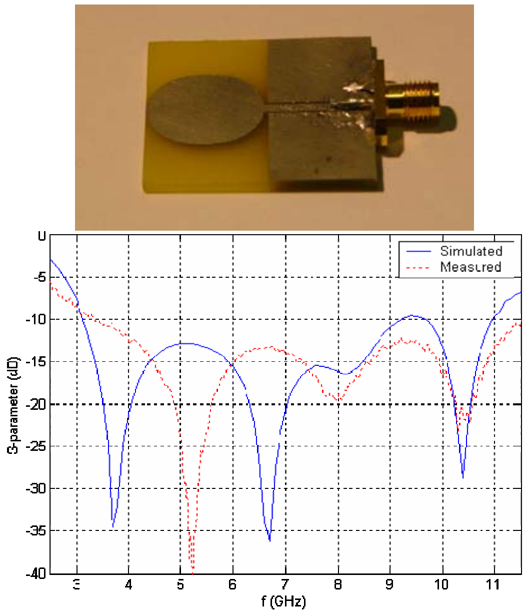

Figure 3 A UWB antenna and its simulated and measured results.

2.2 Warsaw Measurement System

The antenna measurement system at Warsaw University of Technology is a pulse generator based system, a kind of "real" time domain measurement system. The system setup is given in Fig. 4,

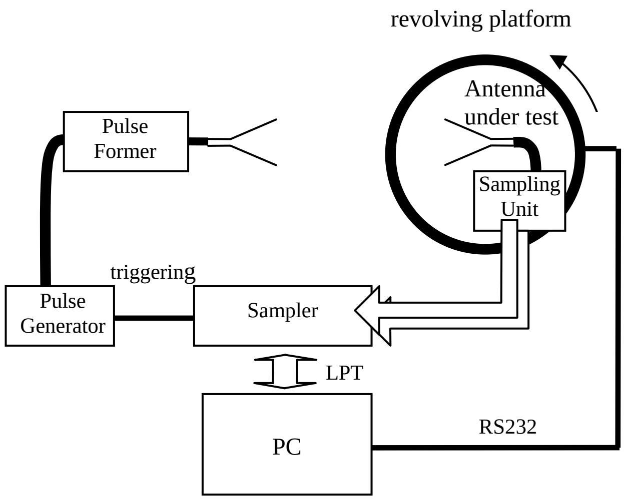

Figure 4 Measurement system setup at Warsaw

The ultra-short pulse is generated by a pulse generator with a compression unit. Such a combination produces a pulse of 30ps width at 3dB level. The output pulse is presented in Fig.5.

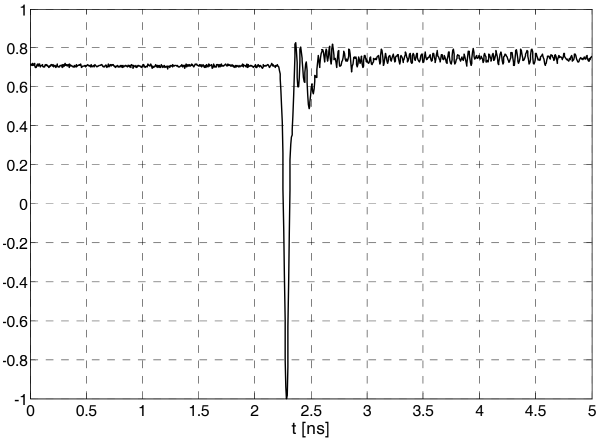

Figure 5 A normalized test pulse

The spectrum of such a pulse extends from zero to over 20 GHz. In practice the range 1GHz – 18 GHz is a good approximation of the equipment limitations. The frequency spectrum of the test pulse is presented in Fig. 6.

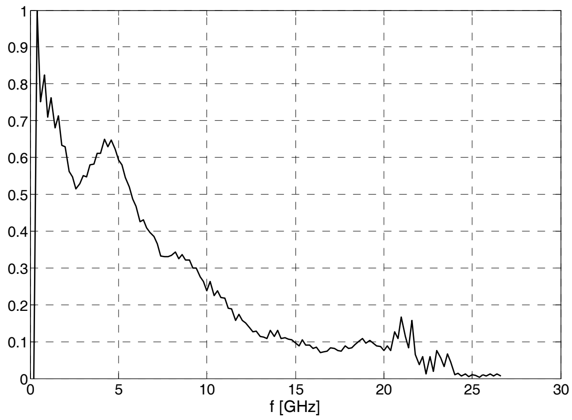

Figure 6 The frequency spectrum of the test pulse

Since sampling such a short single pulse is very difficult, a series of pulses are measured. The pulse generator is triggered by the sampler which allows the utilization of the stroboscopic effect and thus to obtain samples with very high effective sampling frequency. The method is based on the assumption that consecutive pulses are exactly the same and the propagation environment does not change during the measurement procedure.

Since cables and connectors introduce additional distortion to the pulse, both the generator and the sampling unit should be as close to the device under test as possible. Thus it is advantageous to locate sampling unit outside the sampler, close to the device under test.

For the sake of comparison the radiation pattern measurement of the same antenna has been conducted as well in the frequency domain using Agilent frequency domain equipment: tracking generator (83650B) and microwave receiver (8530A) with frequency converter (8511B).

The antenna under test was a wideband lens antenna GZ0126ATP (aperture size 12cm x 9.5cm) operating from 1 GHz to 26 GHz. Frequency domain measurements were conducted form 2 to 20 GHz. The distance between antenna under test and source was approximately 2.5m. A typical set of results are shown in Fig. 7 where the frequency is 5 GHz. The results around the main lobe are almost the same for both the time and frequency domain results. However, for the side-lobes, the frequency domain results are much higher than the time domain results. This is the same for other frequencies.

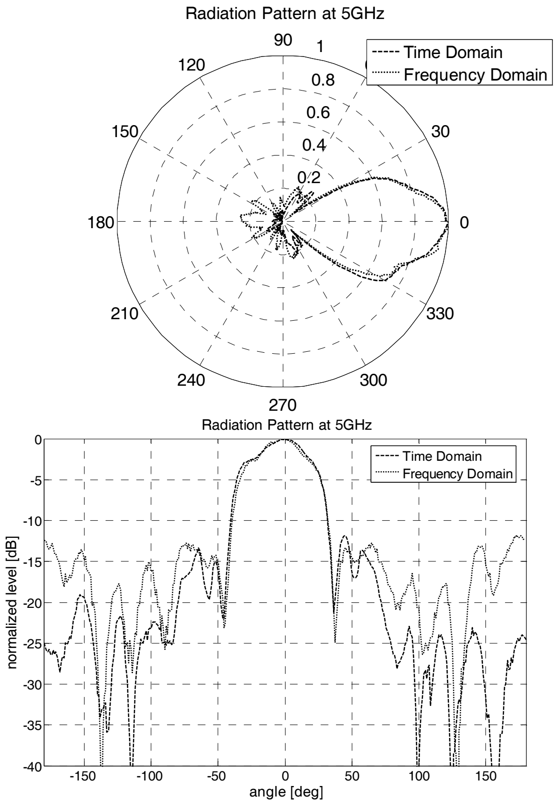

Figure 7 Time and frequency domain radiation patterns corresponding to 5GHz.

2.3 Delft Measurements System

A time-domain measurement system was developed at Delft University of Technology many years ago [3. 5]. The system setup is shown in Fig. 8 which is similar to the Warsaw system. A pulse shaper is also used. The output pulse has got a 3dB bandwidth of about 30 ps (similar to Warsaw's but the pulse shape is different, so is the spectrum) and its spectrum is given in Fig. 9. The spectrum power is changed from almost 60 dB from DC to 18 GHz. A standard X-band horn antenna was measured in both the time and frequency domains. Fig. 10 shows a comparison of the results at the E-plane at 11.23 GHz. A very good agreement between them was obtained over 180 degrees.

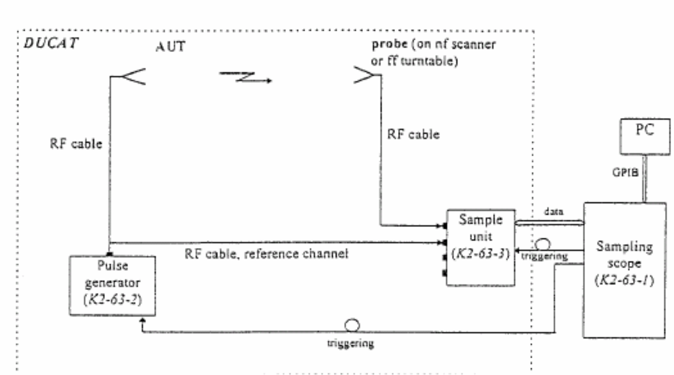

Figure 8 Delft measurement system setup

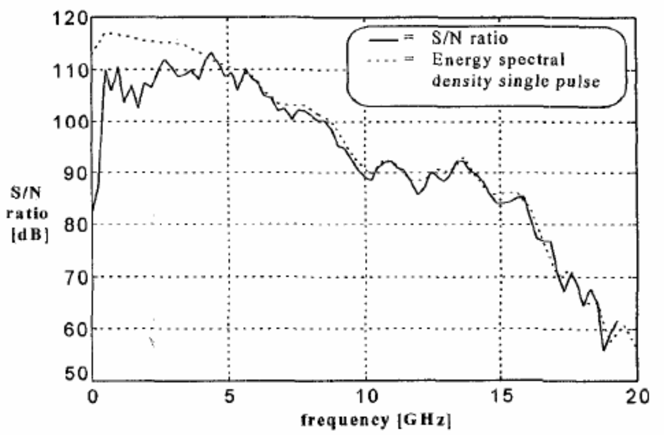

Figure 9 The measured pulse spectrum and S/N ratio

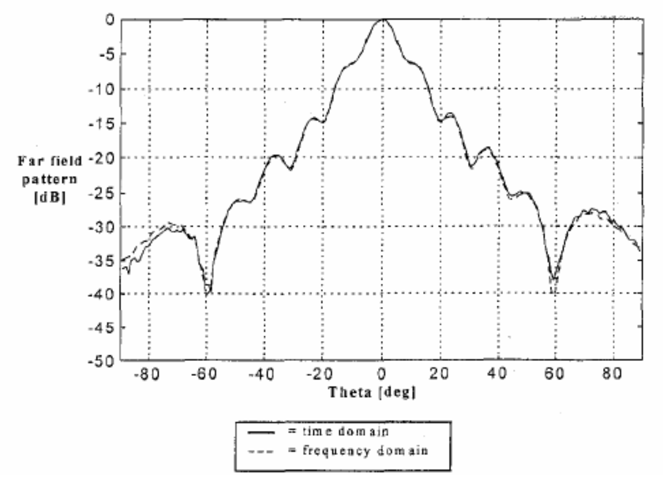

Figure 10 The measured E-plane patterns at 11.23 GHz

3 Discussions

It has been noticed that, in practice, some unique features of the time domain system may be difficult to implement. For example time-gating is very useful to eliminate the reflections in the measurement, but it is actually hard to identify which is the correct window since the reflected signals may be embedded in the desired signal, this is especially true when the separation between the transmitting and receiving antennas is not very large – it cannot be very large if the antenna under test is not very directional, or if large dynamic range is required, or if the chamber size is very limited.

Here three systems from three different organisations have been presented. One is network analyser based and the other two are pulse generator based time domain systems. The latter are similar in setup, but different pulse shapes and spectra are obtained. The measurement results have shown that a considerable difference may be obtained between the time domain and frequency domain results, even for similar measurement systems. This highlights the need for further investigation into the time domain techniques, and also justifies the planned measurement campaign between the organisations. At least three broad band antennas, directional and omni-direction, will be used for this comparison exercise. The comparison results among these three organisations will be presented at the conference.

4 Conclusions

In this paper, the time-domain antenna measurement systems from three organisations have been presented. Some initial results and observations have also been given, it is clear that a measurement comparison among different organisations will be very useful to identify and resolve the problems using either the network analyser based system or the pulse generator based systems.

Acknowledgements

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